

UTILITY APPLICATION

OF

BING CHAO

BENOIT VINCENT

STEPHEN A. KRAUS

TODD P. BEACH

FOR

UNITED STATES PATENT

ON

GOLF CLUB HEAD HAVING A HIGH  
COEFFICIENT OF RESTITUTION  
AND METHOD OF MAKING IT

Sheets of Drawings: Five

SHEPPARD, MULLIN, RICHTER & HAMPTON LLP  
333 South Hope Street, 48th Floor  
Los Angeles, California 90071  
(213) 620-1780

# GOLF CLUB HEAD HAVING A HIGH COEFFICIENT OF RESTITUTION AND METHOD OF MAKING IT

## FIELD OF THE INVENTION

The golf club head and method of the present invention relates generally to a golf club head having a volume of at least 100 cubic centimeters and, more particularly, to a durable golf club head having a thin striking face formed of low density material and having a coefficient of restitution of at least about 0.85.

## BACKGROUND OF THE INVENTION

Modern golf clubs typically have been classified as either woods, irons or putters. The term "wood" is an historical term that is still commonly used, even for golf club heads that are constructed of steel, titanium, fiberglass, or other more exotic materials. Woods constructed of a metallic material are now often referred to as "metal woods." The term "iron" also is an historical term that is still commonly used, even though those clubs are typically not constructed of iron, but rather are constructed of many of the same materials used to construct "woods."

Many advancements have been achieved, particularly over the past two decades, to make it easier to hit longer and straighter shots with woods and irons. In general, golf clubs are now designed to be more forgiving, so that shots that are struck less than perfectly will still have fairly consistent distance and directional control. Moreover, golf club heads now commonly are constructed of combinations of materials, to attempt to optimize the ball flight desired by a particular type of player.

One particular improvement that relates especially to metal woods is the use of lighter and stronger metals, such as titanium. A significant number of the premium metal woods, especially drivers, are now constructed using primarily titanium. The use of titanium and other lightweight, strong metals has made it possible to create metal woods of ever-increasing head sizes.

The head size of metal woods, especially drivers, is often referred to in terms of volume. For instance, current drivers may have a head volume of 300 cubic centimeters (cc) or more. Oversized metal woods generally provide a larger sweet spot and a higher inertia, which provides greater forgiveness than a golf club having a conventional head size.

One advantage derived from the use of lighter and stronger metals is the ability to make thinner walls, including the striking face and all other walls of the metal wood club. This allows designers more leeway in the positioning of weights. For instance, to promote forgiveness, designers may place additional weight at the periphery of the metal wood head and rearward from the face. As mentioned above, such weighting generally results in a higher inertia, which results in less twisting due to off-center hits.

There are limitations on how large a golf club head can be manufactured, which is a function of several parameters, including the material, the weight of the club head, and the strength of the club head. Additionally, to avoid increasing weight as the head becomes larger, the thicknesses of the walls, including the striking face, must be made thinner. As a result, as the striking face becomes thinner and thinner, it has a tendency to deflect more and more at impact, and thereby has the potential to impart more energy to the ball. This phenomenon is generally referred to as the "trampoline effect." A properly constructed club with a thin face can therefore impart a higher initial velocity

to a golf ball than a club with a rigid face. Because initial velocity is an important component in determining how far a golf ball travels, this is very important to golfers.

It is appreciated by those of skill in the art that the initial velocity imparted to a golf ball by a thin-faced metal wood varies depending on the location of the point of impact of a golf ball on the striking face. Generally, balls struck in the sweet spot will have a higher rebound velocity. Many factors contribute to the location of the sweet spot, including the location of the center of gravity (CG) and the shape and thickness of the striking face.

Manufacturers of metal wood golf club heads have more recently attempted to manipulate the performance of their club heads by designing what is generically termed the variable face thickness profile for the striking face. Because of the use of lightweight materials such as titanium for the striking face, a problem arises in the stresses that are transmitted to the face-crown and face-sole junctions of the club head upon impact with the golf ball. One prior solution has been to provide a reinforced periphery of the striking face in order to withstand repeated impacts of the club head with a golf ball.

Another approach to reduce these stresses at impact is to use one or more ribs extending substantially from the crown to the sole, vertically across the face, and in some instances extending from the toe to the heel, horizontally across the face. Because the largest stresses are located at the impact point, usually at or substantially near the sweet spot, the center of the face is also thickened and is at least as thick as the ribbed portions. However, these club heads fail to ultimately provide significant forgiveness to off-center hits for all but the most expert golfers.

5 The coefficient of restitution (COR) for a golf club can be informally defined as a function of the ratio of the relative velocities of a golf ball, just prior to and immediately after impact with the golf club head. The formal equation for the COR value,  $e$ , also accounts for the relative masses of a specific club head and a golf ball, as follows:

$$V_{\text{out}} / V_{\text{in}} = (eM - m) / (M + m)$$

where  $M$  is the mass of the club head and  $m$  is an average mass of the golf ball population.  $V_{\text{out}}$  is the ball rebound velocity and  $V_{\text{in}}$  is the incoming velocity of the ball that is shot at the face of the golf club head using an air cannon, for example.

10 A COR baseline value of  $e=0.822$  has been established for the United States by the United States Golf Association (USGA), although golfers outside of the United States desire and are allowed to use golf clubs having COR values greater than the USGA baseline value. In particular, golfers not abiding by the USGA rules generally prefer golf clubs having the highest COR values, which are currently about 0.85 for drivers.  
15 However, a maximum COR value of about 0.91 is at least theoretically attainable, but manufacturers have heretofore not been able to provide such golf clubs, with sufficient durability, to the public.

## SUMMARY OF THE INVENTION

20 A golf club head of the present invention may have a loft angle corresponding to either a driver or fairway wood. In a preferred embodiment, the head includes a hollow body having a crown, a sole, and a striking plate. The crown has a first thickness of less than about 0.8 mm, for at least a crown transition distance of about 20 mm measured rearwardly from a junction of the crown and striking plate. The sole has a

second thickness of less than about 1.0 mm, for at least a sole transition distance of about 20 mm measured rearwardly from a junction of the sole and striking plate. The striking plate has a third thickness of less than about 2.2 mm, and it is formed of a material having a hardness of at least 30 HRC (Rockwell C), a percent elongation of at least 7%, and a density of less than about 5 g/cc. A club head of this construction has a COR value of at least about 0.85 when the club head has a loft angle exceeding 12 degrees, and it has a COR value of at least about 0.87 when the golf club head has a loft angle of 12 degrees or less.

In another preferred embodiment, the hollow body defines a volume of about 400 cc, and the crown and sole are integrally cast to define a front opening, with the striking plate being welded thereto. The crown has a substantially constant first thickness of about 0.7 mm, the sole has a substantially constant second thickness of about 0.9 mm, and the striking plate has a third thickness of about 1.7 mm, measured centrally on the striking plate. A peripheral thickness of the striking plate is about 0.5 mm less than the third thickness. The striking plate preferably is formed of a titanium alloy comprising by weight about 4% aluminum, 20% vanadium, and 1% tin, wherein the golf club head has a COR value of at least about 0.89.

In another preferred embodiment, the hollow body defines a volume of about 400 cc, and the crown and sole are integrally cast to define a front opening. The striking plate is welded to the crown and sole, close the opening. The crown has a substantially constant first thickness of about 0.7 mm, the sole has a substantially constant second thickness of about 0.9 mm, and the striking plate has a third thickness of about 1.7 mm. The striking plate is formed of an alpha-beta type titanium alloy comprising by weight about 4.5% aluminum, 2% molybdenum, and 3% vanadium. In this embodiment, the golf club head has a COR value of at least about 0.88.

5 A preferred method of manufacturing a golf club head of the present invention includes the steps of: (1) forming a body having a crown, a skirt, and a sole defining a front opening, (2) forming a striking plate of a material having a hardness of at least 30 HRC and a percent elongation of at least 7%, and (3) attaching the striking plate to the body's front opening.

10 The material for the striking plate has a density of less than about 5 g/cc, and the striking plate has a first thickness of less than about 2.2 mm. Further, the crown has a second thickness of less than about 0.8 mm over at least a crown transition distance of about 20 mm measured rearwardly from a junction of the crown and the striking plate, and the sole has a third thickness of less than about 1.0 mm over at least a sole transition distance of about 20 mm measured rearwardly from a junction of the sole and the striking plate. In this method, a club head is formed having a COR value of at least about 0.85 when the club head's loft angle exceeds about 12 degrees, and at least about 0.87 when the club head's loft angle is 12 degrees or less.

15 Additional embodiments of the golf club head of the present invention include striking plates that wrap rearward at least at the crown and sole. The striking plate also may wrap rearward at the heel and toe, thereby forming substantially the entire front portion of the club head. In this manner, the weld joints are moved further from the area of impact with a golf ball, thus increasing the club head's durability. Also, moving the weld joints rearward provides more uniform thicknesses at the face-crown and face-sole junctions and improves quality control during production.

20 Certain objects and advantages of the invention have been summarized above. Of course, it is to be understood that not necessarily all such objects or

advantages may be achieved in accordance with any particular embodiment of the invention. Thus, for example, those skilled in the art will recognize that the invention may be embodied or carried out in a manner that achieves or optimizes one advantage or group of advantages as taught herein without necessarily achieving other objects or advantages as may be taught or suggested herein.

All of these embodiments are intended to be within the scope of the invention herein disclosed. These and other embodiments of the present invention will become readily apparent to those skilled in the art from the following detailed description of the preferred embodiments having reference to the attached figures, the invention not being limited to any particular preferred embodiment(s) disclosed.

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a front elevational view of a first preferred embodiment of a golf club head in accordance with the present invention, showing a weight pad and face insert support tabs in phantom lines.

FIG. 2 is a partial cross-sectional view of the striking face of the golf club head of FIG. 1, taken along lines 2-2 of FIG. 1.

FIG. 3 is a rear elevational view of the striking face insert of FIGS. 1-2.

FIG. 4 is a partial cross-sectional view similar to FIG. 2 showing another embodiment of a striking face insert of the present invention, this embodiment having a constant thickness.



FIG. 5 is another partial cross-sectional view similar to FIG. 2, showing a further embodiment of a striking face insert of the present invention, this embodiment having a variable thickness.

FIG. 6 is a partial cross-sectional view similar to FIG. 2, showing an embodiment of a face plate that wraps radially rearward and substantially horizontally toward the crown and sole of the golf club head.

FIG. 7 is a front elevation view of a second preferred embodiment of a golf club head in accordance with the present invention, showing a junction of the striking face insert with the body near the hosel in phantom lines.

FIG. 8 is an exploded view of the golf club head of FIG. 7, with the striking face insert removed in the direction of the arrow.

FIG. 8A shows a top plan view of the striking face insert of FIG. 8.

FIG. 9 is a chart showing the measured COR values for two embodiments of the present invention, as their face thickness is varied.

FIG. 10 is an elevational view of a golf club head, taken from the toe side of the club head, illustrating a transition region extending from the junction of the striking plate with the crown and sole of the club head.

FIG. 11 is a rear elevational view of a golf club head, showing in phantom lines a weight pad added to achieve a conventional head weight.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

With reference now to the illustrative drawings, and particularly to FIGS. 1 and 2, there is shown a preferred embodiment of a golf club head of the present invention. The golf club head 11 includes a hollow body 13 having a crown 15 and a sole 17, and further includes a striking plate 19. The striking plate together with the body defines a volume of about 410 cc. The crown and sole preferably are integrally cast of Ti 6Al-4V and include toe and heel ends that together define a front opening 21 to which the striking plate is welded. Preferably, the striking plate is formed of a beta-type titanium alloy comprising by weight substantially about 4% aluminum, 20% vanadium and 1% tin. The height of the front of the club head is about 56 mm, measured vertically from the ground to an uppermost face-crown junction.

The crown 15 has a substantially constant thickness of about 0.7 mm, the sole 17 has a substantially constant thickness of about 0.9 mm, and the striking plate 19 has a thickness of about 1.7 mm at a central, circular portion. The periphery of the striking plate is about 0.5 mm thinner, or about 1.2 mm, adjacent to the face-crown, face-sole, face-toe and face-heel junctions of the club head. Because of the thinness of the walls of the hollow body 13 and striking plate 19, the sole 17 preferably has a thickened portion 23 (shown in phantom in FIG. 1) at a central rear location to add mass of about 20 grams. This added mass brings the total club head weight to a more conventional 190 grams. Testing of this golf club head has shown it to have a coefficient of restitution COR of about 0.90 and, in some cases, and as high as 0.91 (see FIG. 9).

The present invention can be embodied in club heads for both driver-type and fairway wood-type clubs. In the former, heads with high COR values of at least about 0.87 are achievable, while in the latter high COR values of at least about 0.85 are

achievable. These values are about 6-10% higher than previously available. Further, for club heads having lofts less than about 12 degrees, durable heads with COR values of at least about 0.88 are attainable.

In the preferred embodiment described above, the head volume is about 410 cc. In alternative embodiments of the present invention, the club head volume is preferably at least about 100 cc and more preferably is at least 300 cc. The sole preferably has a weight member 23 (FIGS 1 and 10) having a mass between 15 and 25 grams, such that the club head has a conventional total weight of between 180 and 210 grams. More preferably, the weight member is integrally formed on the interior surface of the sole and adds about 20 grams such that the total weight of the club head is about 190 grams. Alternatively, the weight member can be separately formed and attached at any location on the club head using methods known to those skilled in the art.

Referring to FIG. 1, the height  $h$  of the front of the club head 11 in the preferred embodiment is about 45-60 mm, and the striking plate 19 preferably has a height  $hf$  of between 35-50 mm. More preferably, the striking plate has a height of at least 45 mm. Preferably the ratio of the width to the height, or aspect ratio, of the striking plate is between 1.0 and 1.7, and more preferably is about 1.6.

The hollow body 13 preferably is cast from Ti 6Al-4V, although other materials having a comparable strength-to-weight ratio and hardness properties alternatively can be used. Methods other than casting to form the body also can be used.

A preferred material for the striking plate 19 is a beta-type titanium alloy, although other metal and non-metallic materials can alternatively be used as long as the mechanical properties of the club head 11 of the present invention as described herein are

present. Beta-type titanium alloys, which have about 10-22% by weight of molybdenum or vanadium, include the following:

Ti 10-2-3 (10% V, 2% Fe, 3% Al)

Ti 15-3-3-3 (15% V, 3% Al, 3% Cr, 3% Zr)

DAT55 (4% Al, 16% V, 6% Cr)

DAT51 (22% V, 4% Al, 1.0% Max. Fe)

SAT2041 (20% V, 4% Al, 1% Sn)

Ti-38644 or Beta-C (3% Al, 8% V, 6% Cr, 4% Mo, 4% Zr)

DAT55 and DAT51 are available from Daido Specialty Steel, of Nagoya-City, Japan. SAT2041 is available from Sumitomo Metal Industries, Ltd. of Japan. The Beta-C alloy is available from RMI Titanium Co., of Brea, California.

Alternatively, an alpha-beta type titanium alloy, e.g., SP700® (4.5%Al, 2% Mo, 3% V, 1% Fe), can be used. SP700® is available from NKK Corporation, of Chiyoda-ku, Japan.

The preferred properties of the striking plate 19 include: (1) an Ultimate Tensile Strength of at least 1400 MPa, (2) a 0.2% Yield Strength of at least 1250 MPa, (3) a Percent Elongation of at least 7%, and (4) a hardness of at least 30 HRC. More preferably, the Ultimate Tensile Strength is at least 1450 MPa, the Yield Strength is at least 1300MPa, the Percent Elongation is at least 7.8%, and the hardness is at least 32 HRC. In addition, the material for the striking plate preferably has a density less than about 5 g/cc.

The striking plate 19 is formed such that the club head 11 has the properties recited above. Preferably, the striking plate is manufactured using cold-forming or cold-working techniques known to those skilled in the art. Processes conducted at ambient temperature, without adding heat, such as hydro press-forming, preferably are used. In the first embodiment of the present invention, the cold-forming technique preferably is utilized such that additional cold-working time is used to create a reduced or stepped periphery for the plate.

In a preferred embodiment, the striking plate 19 is formed of a titanium alloy comprising by weight about 4% aluminum, 20% vanadium, and 1% tin. The sheet of titanium alloy preferably is solution heat treated prior to a cold forming. The cold forming comprises at least 30% cold working of the striking plate. Although, in the various embodiments of the present invention, cold forming may comprise between 15% to 70% for the striking plate. As shown in the embodiment of FIGS. 1-3, an additional 18% cold working is performed to create a reduced peripheral thickness of the striking plate that is about 0.5 mm less than a thickness of about 1.7 mm at a center of the striking plate.

After the final striking plate 19 has been welded to the front opening of the cast body 13, the club head 11 preferably is aged to obtain a higher strength. This contributes to the club head's high COR values.

In an alternative embodiment shown in FIG. 4, a club head body 13 ' is the same as described above, but the striking plate 19 ' is formed of a titanium alloy comprising by weight about 4.5% aluminum, 2% molybdenum and 3% vanadium and it has a substantially constant thickness. In both embodiments, the striking plate is welded

to the cast body's front opening 21. Support tabs 25, (shown in phantom in FIG. 1) or an annular ledge (not shown) can be used to position the striking plate during welding.

FIG. 9 shows measured COR values for the embodiments of FIGS. 1-3 ("Head A") and FIG. 4 ("Head B"). It can be seen that, in general, the COR values vary inversely with the thickness of the striking plate 19, measured at about the striking plate's geometric center. After a maximum COR value that occurs at about a 1.6 mm face thickness, the COR values decline as a result of plastic deformation that occurs due to the over-thinned face structure. Also, the face tends to crack upon impact at thickness lower than about 1.4-1.5 mm. Durability requirements, therefore, lead to production of club heads with face thicknesses substantially higher. In particular, a face thickness of about 2.0-2.2 mm is desirable to achieve a high COR of about 0.88 while having sufficient durability to withstand repeated impacts with a golf ball during normal play.

Other embodiments of a striking plate in accordance with the present invention are shown in FIGS. 5 and 6. FIG. 5 shows a striking plate 19" having a thickness that varies from a thickest point at about its geometric center to lesser thicknesses toward the top and bottom and toward the toe and heel (not shown). FIG. 6 shows a striking plate 19" that extends or wraps toward the crown 15" and sole 17" of the club head body 13" such that at least the top and bottom weld joints lie on substantially horizontal planes formed by the crown and sole. FIGS. 7, 8 and 8A show a striking plate 27 that forms substantially the entire front of the club head and that wraps such that the weld joints are rearward of the forward most surface of the club head that contacts a golf ball.

The embodiments of FIGS. 6-8A include rearwardly wrapped upper and lower portions of the striking plate that form obtuse and acute angles, respectfully, with

the forward portion of the striking plate. The striking plate of FIGS. 7-8A also includes rearwardly wrapped toe and heel portions that join smoothly with the corresponding portions of the club head body. These wrapped portions of the striking plate have thicknesses matching or transitioning to that of the crown and sole, and heel and toe, of the club head body, as required.

The wrapped striking plate may be cold formed or hot forged to obtain the shapes and desired rearward lengths and thicknesses of the upper and lower portions, and heel and toe portions if present. The resulting location of the weld joints for these embodiments, i.e., rearward from the front impact area of the club head, assists in increasing durability of the golf club head and improving COR quality control during manufacture.

Although the foregoing preferred embodiments include a hollow body with a front opening for attachment of a striking plate, alternative methods known to those skilled in the art are available for forming a golf club head in accordance with the present invention without a separately formed striking plate. These methods include, but are not limited to, injection molding and bladder forming techniques, wherein a metallic component incorporating a titanium alloy may be included. Any of the methods described herein may be employed for the golf club head thicknesses, material density and mechanical properties of the present invention, as described herein.

In accordance with the present invention, a majority of the crown of the club head is less than about 0.8 mm thick, and a majority of the sole of the club head is less than about 1.0 mm thick. Preferably, at least transition regions Rc, Rs extending about 20 mm from the junction of the striking plate with the crown and sole portions of

the club head are less than about 0.8 mm and 1.0 mm thick, respectively. This transition region is shown in one preferred embodiment in FIG. 10.

A preferred method of the present invention includes the steps of:

(a) casting a body of a titanium alloy, the body having a crown, a skirt and  
5 a sole defining a front opening, the crown having a substantially constant thickness of less than 0.8 mm, the sole having a substantially constant thickness of less than 1.0 mm;

(b) providing a weight member of about 20 grams onto the sole of the  
body;

(c) cold forming a striking plate having a hardness of at least about 30  
10 HRC and a percent elongation of about 7%, the striking plate having a thickness of less than 2.2 mm and formed from a material having a density less than about 5 g/cc; and

(d) welding the striking plate to the front opening of the body.

The body and the striking plate define a volume of about 400 cc and the  
golf club head has a coefficient of restitution of at least about 0.88.

15 Although the invention has been disclosed in detail with reference only to the preferred embodiments, those skilled in the art will appreciate that additional golf club heads can be made without departing from the scope of the invention. Accordingly, the invention is defined only by the claims set forth below.